Denny-Renton Clay & Coal Co.

Clay Products

General Offices
HOGE BUILDING SEATTLE, WASHINGTON

HINTS ON FARM DRAINAGE.

The Proper Methods and Results of Draining Land.

By Anton Vogt.—Reprinted from "Brick,"

In this article I take occasion to present some thought on the subject of subsoil or, as probably more generally termed, tile drainage, giving reasons for, and some of the results of same, with suggestion for properly laying the tile, and a description of the necessary appliances for better accomplishing the work.

WHY WE SHOULD DRAIN.

There is very little land naturally so dry as not to be susceptible of improvement by artificial drainage, for land is never in a perfect condition in that respect, unless all the rain that falls on it can soak down to the minimum depth required for the healthy development of the roots of cultivated crops, and then find vent, either through a naturally porous soil, or by artificial channels.

Probably no better illustration can be given of the effects of water on growing plants than what we see in the case of plants growing in pots. Every pot is provided with a hole in the bottom, to allow the water to drain out when the soil becomes saturated, and, with the exception of water or bog plants, this drainage is a necessity. If we see a plant whose foliage turns yellow or drops off, or which fails to grow, and whose whole appearance is unthrifty, we are almost sure to find the trouble to be at the roots, and not infrequently we find the drainage is clogged and the roots are inactive. Turning the plant out of the pot, placing some bits of broken crockery at the bottom, and then some coarse material, the plant is returned to its place and filled in with fresh soil, and in a short time it starts into new growth and shows that it can grow if the conditions are suitable. Without healthy roots there can be no vigorous growth. A supply of water is necessary for the roots to take from the soil what they want, but the water must pass off and not remain stagnant, or disease and death will follow. The case is exactly the same with plants growing in the fields where there is an excess of moisture below the surface.

Centuries ago, the Romans, with knowledge of the value of draining, took great care to keep their arable lands dry by means of

open trenches, at least, while we have grounds for believing that they also used covered drains for the same purpose.

Undoubted proof exists that underground channels, by means of burned earthenware, were by them constructed, but whether designed simply for drains, or to carry water to their dwellings is not positively known. Certain it is that land drainage and tile making cannot be claimed as modern discoveries. The trenches of the Romans doubtless served the purpose intended, but the warlike tendencies of that nation made agriculture a secondary matter and prevented any general adoption of draining appliances.

Drainage is a good and permanent investment pecuniarily, and when completed will return to the farmer a high rate of interest on the money invested. The farmer, generally, may be slower in seeing results than the business man of the city, who is readiest to perceive improvements and take advantage of them. He may consider slowly and deliberately, and in some instances cling to old customs, and hesitate to adopt new methods, but when he is convinced of the value of a good thing, he should not be, and by no means is, slow in taking hold of it. It may be true that, possibly, some things have united to make him more cautious in expenditure for improvements, and lead him to think he can, or had better continue, as best he may, in the old ruts of the past, trusting to luck, and possibly good weather, for a limited measure of success. But why take the risk when success can be made certain, and the cost of improvements be returned manifold? When the husbandman can surely double his crop without increasing, but rather lessening, the cost of its cultivation, and when he can make one field give the result of two, why should he hesitate? Your fellow farmers say this can be done, and those who have made the experiment give their experiences in their conversations, each in his own language, but all reaching the same conclusion. One says: "Fields that five or six years ago averaged 25 bushels of grain, now run up to 50 and 60, or even average 70 bushels per acre, once they have been tiled." Another asserts: "That as a result of tiling, one-sixth of increase in produce of grain may be taken as a very low estimate, and in actual result it is seldom less than one-fourth." Another gives as the result of his trials: "That in some cases the product is double, while the expense of working is much lessened."

"A return of 25 per cent increase has been realized, and even more," is the summing up of another. "My experience and observations have been chiefly in clayey soils, where the result of drainage is eminently beneficial, and where I should estimate the increased crop at 6 to 10 bushels (wheat) per acre, while in very wet or swamp land, drainage will increase the value of the land from almost nothing to that of the best," is the testimony of another who has made the trial. Another: "I have a long and varied experience with the tile draining on my farm, and claim that when the

work is well done I have realized 25 per cent on my investment in the increased yield of a single crop."

The consideration of cost need scarcely be considered, if it is true, as asserted, that the increase of crop will pay the expense of tiling even in five years. But it is agreed, by many, that two or three years is the longest time necessary, while often, the increase in the first year's crop pays the cost of underdraining many a farm. For these reasons the under drainage of farms in the north has progressed from, at first, a hesitating, doubting trial, until the present, when one who does not "tile" is difficult to find, while a few years ago he who did drain properly was the exception. Twenty-five years ago "wooden ditches" imperfectly made, and lasting only a few years, were used to some extent in Indiana and other western states. Ohio had already been using, to a limited extent, tile for drainage, and although the work met with bitter opposition, because of the expense, the advocates of progress slowly gained ground, showing their faith even by borrowing money, when necessary, to buy tile, farmers being convinced that, if it paid to borrow money for anything, certainly it might well be done to push drainage. Mark the result. Wet lands yielding from 10 to 25 bushels corn per acre, changed into fields from which 60 to 75 bushels were annually gathered; prices advanced from $30 to $75, or more per acre, and today tile factories are running to their fullest capacity to meet an increasing demand for their products, despite the fact that millions of dollars have already been invested in ditches. We doubt whether there can be found, among the progressive farmers, anywhere, any who, after a faithful trial, are ready to declare their work of tiling even a partial failure, or who would not say that under drainage, with good roads, is the very best investment they have made.

The effect of drainage upon the condition of the soil, and upon growing plants, should be shown, and then the cause for the reputed increase in crops and values would more plainly appear. In this connection, careful examination will satisfy any one that minute rootlets are sent down to an extraordinary depth whenever they are not arrested by stagnant water, and as plants obtain moisture as well as nourishment by means of their roots, the fact is well known that those growing in deep soil, resting on a porous subsoil, seldom or never suffer from drought, while soils which soonest become saturated and run from the surface in wet weather, are precisely those which parch their crops soonest in dry weather. All soils possess, more or less, the power of absorbing and retaining water, and in dry weather the power is constantly operating to supply, from below, the loss taking place by evaporation at the surface. In heavy rains, as soon as the entire mass has drunk to fill, the excess begins to flow off below, and therefore, a deep stratum, or artificial drain, through which water can percolate, but in which it cannot stagnate, is that in which plants are most secure from the

extremes of drought or drowning. Drainage in deepening the soil brings about the foregoing happy condition.

Every one who has attempted to raise deep-rooted vegetables upon half-drained swamp-land has observed the utter impossibility of inducing them to extend downward their usual length. Vegetables on such land frequently grow large at the top, but divide into numerous small fibres just below the surface, and spread in all directions. No roots, except those of aquatic plants, will grow in stagnant water. If, therefore, it is of advantage to have a deep rather than a shallow soil, it is manifestly necessary, from this consideration alone, to lower the line of standing water, at least to the extent to which the roots of our cultivated crops descend. A deep soil is better than a shallow one, because it furnishes a more extensive feeding ground for the roots. The elements of nutrition, which the plant finds in the soil, are not on the surface. Many of them are washed down by the rains into the subsoil, and some are found in the decomposing rocks themselves. These, the plants, by a sort of instinct, search out and find, as well in the depths of the earth as at its surface, if no obstacle opposes. By striking deep roots, again, the plants stand more firmly in the earth, so that they are not so readily drawn out or shaken by the winds.

DRAINAGE ASSISTS PULVERIZATION.

It is manifest that a wet soil can never be pulverized. Plowing clayey, or even loamy soil when wet, tends rather to press it together, and render it less pervious to air and water. The first effect of under draining is to dry the surface soil, and to draw out all the water that will run out of it, so that in early spring or in autumn it may be worked with the plow as advantageously as undrained lands in midsummer. In this

DRAINAGE LENGTHENS THE SEASON

for labor and vegetation. When a wet winter is succeeded, as it often is, by a torrid summer, without the ceremony of an intervening spring, farmers have need of all their energy to get their seed seasonably into the ground. The earth is saturated with water, and the land designed for cultivation frequently cannot be plowed until late in the spring, and all the processes are, necessarily, hurried and imperfect. We know, too, that in such ground the surface becomes hard and bakes quickly, so that it cannot be worked properly. This is not the case with drained land. Drainage

PREVENTS SURFACE WASHING.

All land which is not level, and is not in grass, is liable to great loss by heavy rains. If the land is already filled with water, or has not sufficient drainage, the rain cannot pass directly downward, but runs away upon the surface, carrying with it much of the soil, and washing out what remains of the valuable elements of fertility which have been applied. How many unsightly hills testify to this fact?

If the land is properly drained the water falling from the clouds is at once absorbed and passes downward, saturating the soil in its descent, and carrying the soluble substances with it to the roots, and the surplus water runs away in the artificial channels provided by the drainage process. So great is the absorbent power of drained lands that, after a protracted drought, all the water of a heavy shower will be drunk up by the soil, so that in a day or two none will find its way to the drain, nor will it run upon the surface.

There are no open ditches on drained land, and thus the unsightly appearance so common to many of our farms is avoided, and the ground thus occupied is used to the owner's profit and advantage. It is useless to more than refer to this matter, for the advantage of under drains over the usual ditch is too evident to warrant discussion. By using tile drains, though the drained land may be laid perfectly flat, we secure control of the whole field to divide and cultivate according to convenience, and making it of uniform texture and temperature.

DRAINED LAND IS LIGHTER TO WORK

It is difficult to find one day in the year when a wet piece of land is in suitable condition to plow. Usually such tracts are unequal, some spots being wetter than others, because the water settles in the low places. In such fields the farmer drives his teams knee deep into the soft mud, and finds a stream of water following him in the furrow, or he rises upon a knoll, baked hard and sun-cracked; and one-half of the surface, when finished, is shining with the plastered mud, ready to dry into the consistency of bricks, while the other is already in hard, dry lumps, like paving stones, and about as easily pulverized. This is hard work for the teams and men, hard in the plowing and hard through the whole rotation. The same field, well drained, is friable and porous, and uniform in texture. It may be well plowed and readily pulverized, if taken in hand and at any reasonable season. In this connection, attempts have been made to estimate the saving in the number of horses and men by drainage, and it is thought to be a reasonable calculation to fix it at one in four, or 25 per cent. It will probably strike any farmer as a fair estimate, that on land which needs drainage, it will require four horses and four men to perform the same amount of cultivation that three men and three horses may perform on the same land well drained.

Drained land is least injured by cattle in feeding. A hard upland is less injured by feeding than a low meadow, and the latter less in a dry than a wet season. By drainage, the surface water is taken from the field. None can stand upon its surface for a day after the rain ceases. The soil is compact, and the hoofs of cattle make little impression upon it, and the second or third crop may be fed off with comparatively little damage. Weeds are easily destroyed on drained land, and thus is removed one of our greatest evils. If a

weed be dug or pulled up from land that is wet and sticky, it is likely to strike root and grow again, because earth adheres to its roots, where a stroke of the hoe entirely separates the weeds in friable soil from the earth and they die at once. Again, there are many noxious weeds, such as wild grasses, which thrive only on wet land, and which are difficult to exterminate, but which give no trouble after the land is lightened and sweetened by drainage. This alone will repay the entire cost of draining on some farms.

DRAINAGE PROMOTES ABSORPTION

of fertilizing substances from the air and supplies air to the roots. Plants, if they do not breathe like animals, require for their life almost the same constant supply of air. All plants die in soils and water destitute of oxygen. Absence of air acts exactly in the same manner as an excess of carbonic acid. Stagnant water on a marshy soil excludes air, but a renewal of water has the power to warm a wet soil and to facilitate aeration. Among the advantages therefore of thorough drainage is reckoned, by all, the circulation of air through the soil. No drop of water can run from the soil into a drain without its being supplied with air, unless there is more water to supply it; so that drainage in this way, manifestly promotes the permeation of air through the soil, and thus drainage

ADAPTS THE SOIL TO GERMINATION.

When water is added to perfectly dry soil, it, of course, in the first instance, fills the interstitial canals, and from these enters the pores of each particle; and if the supply of water be not too great the canals speedily become empty, so that the whole of the fluid is taken up by the pores; this is the healthy condition of the soil. If, however, the supply of water be too great, as is the case when a spring gains admission into the soil, or when the sinking of the fluid through the canals to a sufficient depth below the surface is prevented, it is clear that these also must get filled with water so soon as the pores have become saturated. This, then, is the condition of undrained soil. Not only are these pores filled, but the interstitial canals are likewise full; and the consequence is that the whole process of the germination and growth of vegetable is materially interfered with. The great effect of an excess of water is that it produces a corresponding diminution of the amount of air beneath the surface, which air is of the greatest possible consequence in the nutrition of plants; in fact, if entirely excluded, germination could not take place, and the seed sown would of course either decay or lie dormant. The perfect condition of the soil through drainage

AFFECTS ITS TEMPERATURE.

For example, pot-grown plants may still further serve to show a bad effect of a surcharge of water in the soil. All plant growers are

very careful in cold weather about watering their plants at night, knowing by experience that the increased evaporation will too greatly reduce the temperature, and thus check and stunt the plant. The case is the same in effect over large areas where the water is held in the soil below the surface. The temperature is kept many degrees below what it would be if good drainage existed. Vegetation commences later in the spring, arrives at maturity later, and is coarser in texture on such soils. The market gardener, the fruit grower and the farmer cannot afford to raise crops on any but well drained lands.

The excess of water in soil keeps down its temperature in various ways, and the sun has not the power to warm such soil, for several reasons, among which are: 1. The soil is rendered cold by evaporation. 2. Heat will not pass downward in water, so that it can never warm the under soil, except so far as it is conducted downward by some other medium than water itself; and 3. Heat being propogated in water only by circulation, anything which obstructs circulation prevents the passage of heat. Water when in the soil in quantity, in passing into the state of vapor, rapidly carries off the heat which the soil has obtained from the sun's rays. It also carries off heat by evaporation and radiation when present in excess and in a stagnant state; while, on the other hand, stagnant water conveys no heat downward, giving back its heat to the atmosphere only, for although the surface is warmer, the heated water being lighter, remains floating on the surface, while the colder portion continues to sink until the whole has been lowered in temperature to its maximum density, 40 degrees. It is thus that soil overcharged with water is kept at a lower temperature than similar soil with natural or artificial drainage. When rain water can sink freely into soil, to a depth of several feet, and then find ready exit by drainage, in such cases it carries down with it the heat which it has acquired from the atmosphere and sun-heated earth surface, and imparts it to the soil. This has been tested by numerous observations. The importance of the result cannot be well overrated, for although the temperature and other conditions of atmosphere, called climate, are beyond human control, this power of raising the temperature of all wet, and consequently cold, soils becomes tantamount, in some of its results, to a power of improving the climate; there being good grounds for stating that in numerous cases, grain crops have ripened 10 or 12 days sooner than they would have done had not the land on which they grew been drained. Drainage

IMPROVES THE QUALITY OF CROPS.

In dry seasons we frequently hear the farmer boast of the quality of his products. His hay crop, he says, is light, but will "spend" much better than the crop of a wet season; his potatoes are not large, but they are sound and mealy. Indeed, this topic need not be enlarged upon. Every farmer knows that his wheat and corn

are heavier and more sound when grown upon land sufficiently drained.

DRAINAGE PREVENTS DROUGHT.

This proposition is somewhat startling at first view. How can draining land make it more moist? One would as soon think of watering land to make it dry. A drought is the enemy we all dread. Somebody has a plan for producing rain by extensive artificial fires and another by explosives in the air. A great objection to these arrangements is that they cannot limit their showers to particular land, and all the public may never be ready for a shower on the same day. If we can really protect land from drought by undermining it, everybody may at once engage in the work without offense to his neighbor. If a handful of rich soil, or almost any kind, be taken up after a heavy rain, we can squeeze it hard enough with the hand to press out drops of water. If a large quantity of the same soil should be taken up after it was so dry that not a drop of water could be pressed out by hand, and subjected to the pressure of machinery, we would force from it more water. Any boy who has watched the process of making cider with the old-fashioned press, has seen the pomace, after it had once been pressed apparently dry and cut down, and the screw applied anew to the "cheese," give out quantities of juice. These facts illustrate first, how much water may be held in the soil by attraction. They show, again, that more water may be held by a pulverized soil than a compact one. This increased capacity to contain moisture by attraction is the greatest security against drought.

After more rain falls than the ground can readily absorb, the excess settles into the drains and flows away, leaving the soil in a suitable condition for the roots of growing plants. But in dry time the air upon the surface is heated by the sun's rays that are absorbed by the top layer of soil. This heated air expands and rises just as warm air rises from the heated stove. At the same time warm air enters the open ends of drains, passes along them and constantly ascends through the soil to take the place of the heated air rising from the surface. But all the soil below an inch or two of surface is cooler than the air that enters the pipes, and this being cooled, deposits its previously concealed vapor, so that, in fact, it moistens the ground.

We can thus understand why under draining not only carries off excess water, but also dampens the soil when it is dry. Stirring a dry soil with hoes or cultivators in hot weather brings hot moisture-laden air in contact with soil colder than itself, and it deposits moisture upon it. Another important effect of such drains or air passages is, that air passing through the soil oxidizes portions of the plant food in it, both mineral and organic, and thus increases the fertility. It also often destroys poisonous substances in the soil like the prosalts of iron, which the access of air changes into the innocuous peroxide.

Particularly does the foregoing apply to all clayey soil. There are occasionally stiff clayey soils, which are, in their natural state, impervious to water, or nearly so, and these are the very soils which without drainage, are perfectly worthless. It would seem at first view, that such soils could not, from their constitution, be susceptible of drainage, and were it not for a provision of nature, which seems to specially aid our labors, such lands must be given over as hopeless. But, all soils, and clays in particular, expand when wet and contract when dry. When drains are laid in clay the soil next to the tiles is deprived of its water and, of course, rendered drier than the rest. This causes it to crack, and the cracks are found by observation to commence at the drains and extend further and further in almost straight lines, into the subsoil, forming minor drains or feeders, all leading to the tiles. These main fissures have numerous smaller ones diverging from them, so that the whole mass is divided and sub-divided into the smallest portions. The main fissures gradually enlarge as the dryness increases, and at the same time lengthen out, so that in a very dry season they may be traced the whole way between the drains. In addition to the evils enumerated it is well known that wet land, if in grass, produces only the coarser varieties and many sub-aquatic plants and mosses of no value for pasturage; its herbage is late coming in the spring and fails early in the fall, and animals grazing on it are unduly liable to disease. When such land is used for cultivation operations are easily interrupted by rain and the compactness and toughness of the soil renders labor more arduous than is necessary on dry lands. With all the usual precautions, the best seed time is often missed, and this usually proves the prelude to a scanty harvest. Even the breaking of the subsoil and the deep tillage so beneficial in other circumstances, is generally injurious on such land, as it but increases its power of retaining water. Doesn't every farmer know these to be facts? And yet, despite the testimony of the past and present, as well as the progressive spirit of late years in portions of our own and other countries, how true is it that underground drainage is almost unknown among our farmers of the South. The want of success with so many is attributed to "accidents" which, when examined, are found to result from causes that thorough drainage would certainly remove. It would seem from the remarks of those who till the earth that there never was season just right, that rains had been sent down so plentifully and at such wrong seasons as to always blight our harvests. It is rare, it would appear, that we do not have "a most remarkable" season with respect to moisten especially. Our potatoes, our corn, our cotton are rotted by the summer showers or cut off by a summer drought. No man admits that he lacked skill to cultivate his crop, and seldom does a farmer attribute his failure to the poverty of his soil. He has planted and cultivated in such a way that in a favorable season he would have reaped a fair reward for his toil, but, as has been claimed, the

season unfortunately has been too wet or too dry. Still with full faith that farming will pay in the long run, our friend resolves to plant again, the same land in the same manner, hoping for the future, better luck that seldom comes. Too much cold water is at the bottom of most of these complaints of unpropitious seasons, as well as at the bottom of most of the soils, and the evils can only be removed, or at least lessened, by thorough drainage, by which, as we trust we have shown, the stagnant water is removed to a proper depth, a free passage for rain water and air established from the surface to the level of the drain, thus speedily affecting most important changes in the condition of the soil, making it more friable and enabling plowing and other tillage operations to be more speedily performed; moderate rains cease to arrest such operations and heavy rains cause a much shorter interruption of such work. Deep tillage aids the drainage and is in every way beneficial, helping to make earlier seed time and finer harvest, better crops and healthier live stock and is a part of all judiciously conducted drainage operations. In a word, we may estimate the profits of tile drainage at from 10 to 30 per cent, and sometimes the profits considerably exceed these figures. For every dollar's worth of improvements we put on our farms we must make a corresponding improvement in our methods of farming, and thus proportionately increase our harvests. When, then, we make our farms dry and drive our fields to the full limit of their productive capacity, we shall realize and reap the full measure of the profits of tile drainage and of improved agriculture.

I have thus far referred to the effect of drainage on the condition and value of the land, and thus more directly on the labor and pocket of the farmer. There are, however, questions of vastly greater importance affecting not only the pocket, but the health and it may be the very existence, of you and yours, that of

SANITARY DRAINAGE.

Next to life, the most precious possession is health, and the conditions of health have been laid down as pure air, pure water and pure food. Atmospheric temperature and moisture, which are the controlling forces in climate, have also intimate relations to health. The human body, amid conflicting changes of temperature, must still maintain a temperature of 98 degrees F., for to fall much below or rise much above causes diseases, and if continued for many hours, death. Since the soil on which man lives affects the composition of the air overlying it, has a profound influence upon the water contained within it, and a marked control over the local temperature, it becomes evident that the soil itself, and the physical condition of the soil, must have a marked influence on the health of its inhabitants. Very obviously the soil is the physical basis of life.

PART II.

The drainage of swamps and marshes and the removal of all stagnant surface water have been so beneficial to the health of the community, that no one in this age questions the result. In a state where one-ninth of the surface is indicated upon the original survey as swamp, the benefit to the general health must be obvious. The malarial diseases of the state of Tennessee have been reduced one-half and the most potent factor of this reduction is drainage of swamps. No law ever placed upon the statute books has been productive of more good and less evil than the law providing for compulsory drainage, where each land owner was compelled to bear his just part of the burden and no churl could block the drainage of a whole neighborhood because he chanced to control the outlet. This law has paid the state ten-fold the cost of reclaiming a large area of once worthless land, and it has paid a hundred-fold in promoting the public health.

UNDER DRAINAGE.

Since surface drainage needs no advocate today, I turn my attention to a form of drainage equally necessary, but the need of which is not so obvious. I refer to the under draining of soils whose surface appears reasonably dry, but whose deeper recesses are full of stagnant water. Such water is never to be mistaken for soil moisture, or water held in the soil by capillary attraction, but is the free water of soil, which will flow under the action of gravity, and has been named ground-water by the Germans.

This ground-water diminishes in a marked degree the agricultural capabilities of the soil, lowering the temperature, preventing soil oxidation, arresting the elaboration of plant food and preventing the free spreading of the roots in the soil; because the roots of most cultivated plants will die in stagnant water. I do not propose, however, to discuss the agricultural value of drainage.

GROUND-WATER AND HEALTH.

The influence of ground-water on health is equal in importance to its influence on crops. No matter how fertile the soil, if the farmer, by reason of sickness, is unable to sow, harvest and garner the golden grain. I call your attention in particular to this influence of ground-water present in the soil in consequence of imperfect drainage, because people are only beginning to realize how profound is the influence of ground-water on the health. This influence is exerted directly in three ways. By making the soil and the air above it cold, by making both damp, and by generating malaria; indirectly, the ground-water is the predisposing cause of a large number of diseases. The average annual rainfall, as determined by observation, is 32.18 in.

This is the average rainfall, some years more than this and some years less. This rain water will be disposed of in three ways: 1.

Used up by growing plants and evaporated by the leaves and stems. 2. Flowing away either over the surface or by subterranean channels. 3. Evaporation. When we speak of so many inches of rainfall we seem to be dealing with small quantities of water, but the gross amount is really large. Thus, one inch of rainfall means 112 tons of water to the acre, and the annual rainfall on each acre is 3,600 tons.

LOSS OF HEAT.

The mean rainfall for six months, from April to end of September, is 19⅓ in. Suppose an acre is planted in corn, producing 20 tons, and, assuming that it will evaporate from its leaves and stems during the period of growth thirty-six times this weight, then 720 tons of water—say 6⅓ in. of rainfall—will be used by the growing crop, leaving 13 in. to be disposed of in the six months by flowage and evaporation, which will take place from the surface of any moist soil, six inches of the semi-annual rainfall is made way with, and the remaining seven inches would flow away by subterranean channels if such were provided. In their absence, this mass of water can be disposed of only by an increase in the natural evaporation. Evaporation is a powerful cooling process. To evaporate one pound of water will consume an amount of heat sufficient to raise the temperature of five and one-half pounds of water from freezing point to boiling heat. By evaporating such a mass of water the temperature of the soil is lowered to a surprising degree, with a corresponding loss of active force for the use of vegetable life. If we attempt to make good this loss of heat by unnecessary evaporation, and to restore the normal temperature of such a soil, it would require all the heat caused by burning 65 tons of coal for each acre. No wonder the farmer calls such a soil clay. Any means by which we can draw off this water without evaporating it will be a large addition to the available temperature of the soil during the growing season. Every tile that discharges five tons of water a day for six months saves an amount of heat equivalent to 75 tons of coal.

It is a physical necessity that a water-soaked soil should be a cold soil during all our so-called hot season. The evils springing from this cause are more manifest in spring and early summer, but it is at this period that tile drains are most active. It is at this season, also, that animal and vegetable life alike demand warmth.

CHILLED AIR.

But the evaporation of so much water renders the air over such a soil damp and chilly. This result is a physical necessity. This damp and chilly atmosphere has a more serious influence than the simple feeling of discomfort. It has a most depressing influence on the human system, lowering its tone, enfeebling the vital powers and acting as the pre-disposing cause of a long list of diseases, some of them the most destructive and incurable known to

medicine. The depressing influence of the dampness and chillness of water-soaked soil is not to be compared to the effect of an occasional wetting, as when we are caught in a shower. The chilly dampness of the undrained soil is persistent and unremitting, dragging us down with its cold fingers at all hours of "noon of day and noon of night", as if we labored and rested, waked and slept in a perpetual drizzle of cold rain. It may seem a small force at first, but its persistent, untiring and relentless pull tells upon the strongest at last, like the invisible fingers of gravity which finally drag down all to a common level, whether towering oak or cloud-piercing mountain. This depressing influence is not developed suddenly and distinctly. An hour, a day, a month, may show no marked deterioration, else man would flee from such places as from a plague spot. But silently and secretly the sapping and mining go on until the crash comes in sickness, suffering, and the sleep that is eternal.

SOIL BREATH.

There are certain other conditions secured by drainage of the soil which are essential to the health of the inhabitants, and one of these is aeration of the soil, or the passage of air through the pores of the soil. The air is entirely excluded from a water-soaked soil; the entrance of air is prevented and all interchange between the air and soil—all soil breath—is prevented. Have you ever thought how everything breathes, animate and inanimate alike? You inspire and expire air continuously and thus keep yourself in good condition, and so does your coat and jacket. The air penetrates every fibre of your wardrobe, passing in and out, and carrying out something it did not carry in. If your clothing was impermeable to air you could not tolerate it for an hour. The invisible waves of air wash and purify you every hour.

If you suppose your clothes do not breathe, place them in an air-tight box and strangle them for a few months, when the musty smell will convince you that your clothes must breathe to remain sweet and wholesome. Even the solid bodies, such as wood and stone, are still washed and infiltrated with air. Here is a stick of red oak a foot long, and you see I can readily blow air through it. Here is a roll of mortar, such as masons use in plastering walls, and you see I can, with the slightest effort, blow air through four inches of dry plaster. Not only can the air pass through these bodies, but it does pass under natural conditions, and plastered walls breathe. In plastered rooms where the walls have been left undisturbed for some time, you see the position of every beam and joist, and even the lath, by the light color of the wall. The part of the wall occupied by the plaster only is more permeable by the air, which, in passing through, leaves the dust behind, forming a brown streak.

Under proper sanitary conditions the air passes in and out of the

soil with every motion of the wind. You will be surprised to see how readily air may be made to pass through dry soil. A jar 14 in. high may be filled with compact dry soil, the top closed with a doubly-perforated cork; through one hole passes a glass tube to the bottom of the jar, terminating above in a horizontal jet; through the other hole a tube passes to the space above the soil. On blowing into this tube gently, you see the air passes down through 14 in. of soil, because it escapes freely at the horizontal jet of the other tube, as is shown by blowing the candle flame before it. Take a tube 5 ft. long and mounted in the same way, and you can force air through dry sand and sway the candle flame by the escaping air.

WATER STOPS SOIL BREATH.

But all this is changed by the presence of water in these materials. If the walls of the house are wet, the passage of air is prevented. In the same way, if the soil is drenched with water the passage of air is prevented. It will pass through 14 in. of dry soil more easily than through 4 in. of wet soil. Indeed, the air will not pass at all through a thin stratum of wet soil, but will readily pass through a thick stratum of dry soil. You thus see that a drenched soil is a drowned soil; that all the conservative influences secured by the interaction of soil and air are cut short by the presence of ground water.

The sanitary report for England, some years ago, gives the following conclusions in respect to the influence of soil dampness:

1. Excess of moisture, even on lands not evidently wet, is a cause of fogs and damps.

2. Dampness serves as a medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effect of such matter in the air; in other words, the excess of moisture may be said to increase or aggravate excess in impurities in the atmosphere.

3. The evaporation of the surplus moisture lowers the temperature, produces chills, and creates or aggravates the sudden and injurious changes of temperature by which health is injured.

4. Catarrh and rheumatism are natural products of the chills and damps of an undrained soil. Diarrhœa, dysentery and malarial fevers are very common and very severe in type in districts where ground water abounds and the water-line approaches the surface.

Finally, extensive researches in England, Germany and America have established the fact that undrained soils greatly promote consumption. This fell disease, the direct cause of one-seventh of the deaths in the world, finds its favorite haunt in the water-logged soil. This is no wild guess, thrown out to be the sensation of the hour, but it is sustained by a vast array of facts, and is a result independently reached by separate investigators in widely separated

countries. However precarious may be the field crops on a water-soaked soil, the abundant house crop of consumptives may be safely counted upon. The entailments of living on water-soaked and undrained soils, therefore, are catarrh, ague and rheumatism in the spring; diarrhœa, dysentery and fever in the hot months; pleurisy, pneumonia and diphtheria in the cold months, and consumption all the year round. We have histories of races and dynasties, their rise, progress and decline, the causes which brought them into prominence, and the forces which brought them to their downfall. Why should not a soil have likewise a history of its own and take on a personality as truly as a race? Let us scan the features of such a farm and follow the history springing from its inherent qualities. The surface is somewhat level, or gently undulating, the soil a tenacious clay, strong in the elements of enduring fertility, if the physical conditions are properly adjusted. The natural drainage is very slight, except that much of the surface water can run off by overflow, but the tenacious quality of the soil prevents all deep drainage; the deeper soil is water-soaked in the spring and early summer, and at other times when heavy rains fall; gate and fence posts are heaved by the frosts; winter wheat and clover are half uprooted by the same force. Work is late in the spring because the soil is cold and wet, crops are slow to start and slower to ripen. The farmer "has a hard row to hoe." A hopeful and cheerful spirit is conspicuously wanting because he has generally poor success with his crops, "bad luck", and because he has the continuous depression of poor health. The furrows seam his cheeks early, his shoulders stoop when he should stand erect in manhood's prime.

Indoors the wife soon fades, the bloom and laugh of happy girlhood give place to the chronic invalidism of motherhood. Children are born only to die, or linger on in joyless ill health. The family is finally blotted out, unless a surviving son may hand down this heirloom of sorrow to another generation, when the farm passes into other hands to repeat the same story. And thus we see in hopeless succession the generation of joyless owners pass before our eyes. The doctor, the undertaker, and the sheriff enter in succession to shift the stage scenery, but the sad drama goes on with little variation.

Is this all a fragment of the imagination? Can you not tell of farms where many of these features can be traced in the water-soaked soil? Examples of this kind might be quoted by the hour. But when houses are built upon retentive water-soaked soils, and no means employed to take off the ground water or ward off its effects, the harvest of woe is sure, though it may be slow to ripen.

DISTANCE AND DEPTH OF DRAINS.

What should be considered the minimum depth to which soil should be drained to obtain the greatest benefit therefrom, has

been, and still is, a subject of considerable controversy. From what has been stated in the previous pages of this article, the proper depth should be nearly determined by any one who gives the matter necessary attention. Still, a few more thoughts may not be out of place.

Water runs steadily through sand or gravel. In such soils it easily seeks and finds its level. If it be drawn out at one point, it tends toward that point from all directions. In a free, open sand, you may draw all the water at one opening, almost as readily as from an open pond.

Yet, even such lands require draining. A body of sandy soil frequently lies not only upon clay, but in a basin, so that, if the sand were removed, a pond would remain. In such a case a few deep drains rightly placed would be sufficient. This, however, is a case not often met with, though open, sandy soil upon clay is a common formation.

Then there is the other extreme of compact clay, through which water seems scarcely to percolate at all. Yet it has water in it, that may probably soak out by the same process by which it soaked in. Very few soils of even such as are called clay, are impervious to water, especially in the condition in which they are found in nature. To render them impervious, it is necessary to web and stir them up, or, as it is termed, puddle them. Any soil, so far as it has been weathered—that is, exposed to air, water and frost—is permeable to water to a greater or less degree; so that we may feel confident that the upper stratum of any soil, not constantly under water, will readily allow the water to pass through. And in considering the drainage of stiff clays, we have seen that the most obstinate clays are usually so affected by the operation of drainage, that they crack and so open passages for the water to the drains. All gravels, black mud of swamps, and loamy soils of any kind, are readily drained.

The relations of the depth and distance of drains should be more fully considered in treating of the depth of drains. The idea that depth will compensate for frequency in all cases, seems now to be abandoned. It is conceded that clay soils, which readily absorb moisture, and yet are strongly retentive, cannot be drained with sufficient rapidity, or even thoroughness, by drains at any depth, unless they are also within certain distances.

In a porous soil, as a general rule, the deeper the drain the farther it will draw. The tendency of water is to lie level in the soil; but capillary attraction and mechanical obstructions offer constant resistance to this tendency. The farther water has to pass in the soil, the longer time, other things being equal, will be required for the passage. Therefore, although a single deep drain might in 10 days draw the water all down to its own level, yet it is quite evident that two drains might do the work in less time—possibly in five days. Yet, if we adopt the conclusion that four

feet is the least allowable depth where an outfall can be found, there may be the question still, whether, in very open soils, a still greater depth may not be expedient, to be compensated by an increased distance. The sudden rising of water in many of our streams, with the attending overflow of much of our best land, so liable to occur about planting time, required that our system of drainage should be efficient, not only to take off large quantities of water, but to take them off in a very short time. How rapidly water may be expected to pass off by drainage is not made clear by writers on the subject. Probably 3-in. tile, at 50 ft. distances, will carry off, with all desirable rapidity, any quantity of water that will ever fall, if the soil be such that the water can pass through it to the distance necessary to find the drains; but it is equally probable that, in a compact soil, 50 ft. distance is quite too great for sufficiently rapid drainage, because the water cannot get to the drains with sufficient rapidity.

While we would not lay down an arbitrary arrangement for any farm, and while we would by no means advocate what has been called the gridiron system of drain everywhere at equal depths and distances, yet some system is absolutely essential, in any operation that approaches to thorough drainage.

The depth of, and distance between, laterals, should be governed by the nature of the soil, whether clay, gravel or sand. If the main is 6 in. in diameter and laterals 3 in. in clay soil, let the laterals be 30 to 40 ft. apart. Laterals should enter the mains at an angle of from 15 to 20 degrees and thus avoid the obstructions liable to gather at the connection where a short bend is used. Six inches fall in each 100 ft. is sufficient, if care is taken to have the greater fall at the lower end, or outlet, to prevent obstruction. The expense of draining is difficult to determine, for, naturally, it also depends on the soil and circumstances. In ordinary cultivated fields a great deal of the work can be done with the plough, and the filling in, after carefully laying the tile, can be done with scrapers.

If it be only desired to cut off some particular springs, or to assist nature in some ravine or basin, a deep drain here and there may be expedient; but when any considerable surface is to be drained, there can be no good work without a connected plan of operations. Mains must be laid from the outfall, through the lowest parts; and into the mains the smaller ones must be conducted, upon such a system as to insure proper fall throughout, and that the whole field shall be embraced.

Again a perfect plan of the complete work, accurately drawn on paper, should always be preserved for future reference. Now it is manifest, that it is impossible to lay out a given field, with proper mains and small drains, dividing the fall as equally as practicable between the different parts of an undulating field, preserving a system throughout, by which, with the aid of a plan, any drain

may at any time be traced, without making distances conform somewhat to the system of the whole.

In conclusion as to distances, I would advise great caution on the part of beginners in laying out their drains. Draining is too important and expensive a work to be carelessly or unskillfully done. A mistake in locating too far apart brings a failure to accomplish the end in view. A mistake in placing them too near involves loss of time and money. Consult, then, those whose experience has given them knowledge, and pay to a professional engineer, or some other skillful person, a small amount for aid, which will probably save ten times as much in the end.

Now let us consider the necessary size of tile to use under various conditions. It is shown statistically that the maximum rainfall per hour is about one inch. One inch of rainfall per hour gives 22,633 gallons per hour for each acre, or 377 gallons per minute per square acre.

It is proven, also, that owing to obstructions not over 50 to 75 per cent of the rain falling will reach the drain within the same hour. Due allowance should be made for this fact in determining the size of tile required, as severe storms are generally of short duration. Remembering these points, the following table showing the number of gallons discharged per minute for specific sizes and grades of tile, will assist in determining the size of pipe to be used in the work.

CARRYING CAPACITY—GALLONS PER MINUTE.

Diameter of Tile in inches.	1½ in. fall per 100 ft.	3 in. fall per 100 ft.	6 in. fall per 100 ft.	9 in. fall per 100 ft.	1 foot fall per 100 ft.	18 in. fall per 100 ft	2 ft. fall per 100 ft.	3 ft. fall per 100 ft.
2½	14	20	28	34	40	49	55	68
3	21	30	42	52	60	74	85	104
4	36	52	76	92	108	132	148	184
5	54	78	111	134	159	192	219	269
6	84	120	169	206	240	294	338	414
8	144	208	304	368	432	528	592	736
9	232	330	470	570	660	810	930	1140
10	267	378	563	655	803	926	1340	1613
12	470	680	960	1160	1360	1670	1920	2350
15	830	1180	1680	2040	2370	2920	3340	4100
18	1300	1850	2630	3200	3740	4600	5270	6470
20	1760	2450	3450	4180	4860	5980	6850	8410
24	3000	4112	5871	7202	8303	10021	11743	14466

TOOLS AND IMPLEMENTS.

The implements convenient for drainage depend on many circumstances. They depend upon the character of the earth to be moved. A sharp, light spade, which may work rapidly and well in a light loam or sand, may be entirely unfit to drive into a stiff clay; and the fancy bottoming tools which may cut a soft clay or

sand in nicely measured slices, will be found quite delicate for a hard-pan or gravel, where the pickaxe alone can open a passage.

One man works best with a long handled spade, another prefers a short handle, one drives it in the earth with the right foot, another with the left. A laboring man in general, works best with such tools as he is accustomed to handle; while theorizing implement-makers, working out their patterns by the light of reason, may produce such a tool as a man ought to work with, without adapting it at all to the capacity or taste of the laborer. A man should be measured for his tools, as much as for his garments, and not be expected to fit himself to another's notions more than to another's coat.

If the land owner proposes to act as his own engineer the first instrument he will want to use is a spirit level, or some other contrivance by which he may ascertain the variations of the surface of his field. The natural way for a Yankee to get at the grades is to guess at them, and this practically is what is usually done. Ditches are opened where there appears to be a descent; and if there is water running, the rise is estimated by its current; and if there is no water rising in the drain, a bucketful is occasionally put in to guide the laborer in his work. No one who has tested the accuracy, or rather inaccuracy, of his judgment as to levels of fields can at all appreciate the deceitfulness of appearances on this point. The human eye will see straight but it will not see level without a guide. It forms conclusions by comparisons; and the lines of upland, of forest tops and of distant hills, all conspire to confuse the judgment, so that it is quite common for a brook to appear to the eye to run up hill, even when it has a quick current.

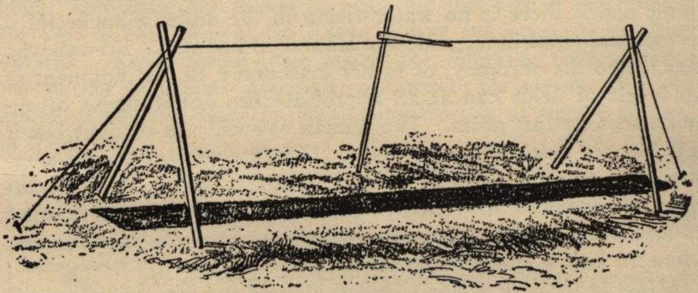
A few trials with a spirit level will cure any man of his conceit on this subject.

And so it is as to the regular inclination of the bottoms of drains It is desirable not only to have an inclination as nearly as possible, especially if the descent be small. Workmen are very apt to work at a uniform depth from the surface line; and thus at one point there may be a fall of one inch in a rod, at another twice that fall, and at another a dead level or even hollow. We have found in 12 rods a variation of a foot in the bottom line of a drain opened by skillful workmen on a nearly level field, where they had no water to guide them, and where they had supposed their fall was regular throughout.

The following device has proved so satisfactory in an experience of several years that it is now thought to be almost indispensable. Two strips of pine board or other light wood about 7 ft. long and 2½ to 3 in. wide, are joined by a small carriage bolt placed about 6 in. from the upper end, and forming shears as represented. The lower end of these strips should be square so that they will not readily settle into the ground when pressed from above.

The line, which should be small and strong like a mason's line, passing over the fork at the upper end of the shears, should be wound once around one of the arms to prevent slipping, and then fastened to a peg driven in the ground some six feet from the foot of the shears and nearly in line of the ditch. If the peg is driven nearer the foot of the shears than the height of the line above the ground, the strain will be greater on that part of the line between the top of the shears and the ground than it is between the shears, and the line will be liable to be broken near the end when subjected to the necessary tension.

The smaller the line the better, if it has the required strength, as it is less liable to sag between the shears. To prevent the line from sagging when the shears are quite a distance apart, "gage stakes" of the form to be described, are placed at convenient intervals along the ditch between the shears. A round rod of hard wood, about 7 ft. long and 1½ in. in diameter (a long fork handle will answer), forms the vertical part of the gage. This rod should have a sharp point at the lower end (which can be readily made



from a piece of gas pipe), and an iron band at the upper end to prevent splitting when driven into the ground. The horizontal arm, about 2 ft. long, should be 2 x 2½ in. at the end through which the vertical rod passes, and tapering, for the sake of lightness, to ¾ of an inch square at the opposite end. A rivet should be put through the base of the arm, back of the key, to prevent splitting. The vertical rod is driven into the ground near the edge of the ditch, and the horizontal arm is slid up until the sag of the line is corrected, when it is secured by the key, which clamps it to the rod.

In laying tile from three to four feet deep my practice has been to adjust the line seven feet above and parallel to the desired grade, and then to make use of a 7 ft. measuring staff to determine the depth of excavation required below the line. If the ditches are deeper the line can be placed higher and a longer measuring staff used to correspond to the increased height. When working with a 7 ft. staff, if all but the last foot of the excavation is made before the line is put up it will not be in the way, as it is high enough to allow a man to work when standing in the ditch.

The illustration given shows the shears and gage-rod supporting the line in place over the ditch, and will give a better idea of this device for getting the grade than any description.

EFFECT OF DRAINAGE.

The effects of drainage upon the soil are very plain and important. The roots of the plants in the undrained soil are confined near the surface, cut off by the water line, the plant yellows and dwarfs. The roots of the plant in the undrained soil run down, and spread out in search of supplies, hence the vigorous growth.

That a deep soil is better than a shallow one, is well known to every observing farmer. We say of certain fields "the soil is thin", by which we mean that the field has a shallow feeding ground, for the roots of our crops will not grow in the water. Then a deep soil is better than a shallow one because the roots descend much deeper for plant food. In retentive clay soils we can have a depth of active soil as deep as we drain. Corn roots have been found at a depth of eight feet and wheat roots at a depth of five feet.

A drained soil becomes a great laboratory in which is prepared the necessary supply of food for the growing crop down as deep as the tile is laid. The water passing down through the pores to the drain below, is followed by the air absorbed by the soil, which the roots, following down through the same spaces, take up.

DRAINAGE INSURES CERTAINTY OF CROPS.

The cultivator of level undrained land is continually harassed in mind about the uncertainty of his business. He must wait until the season is well advanced to plow his land. Then if he plants, he is uncertain whether the weather will be favorable or unfavorable. It may "turn off wet" and the constant evaporation, keeping the land cold, causes the seed to rot. If the season be favorable for the germination of the seed, and the young and tender plants appear, then it may turn off showery, and the land becomes so wet as to place it out of his power to cultivate it, and the crop turns out badly; or if the season be dry in the after part, the land which is naturally wet will dry out and become hard and the crops damaged. Hence it is that such a farmer must plod along on uncertainties, accept his fate and blame Providence.

But the farmer who cultivates land which is thoroughly underdrained, can break it a week or 10 days earlier in the spring; the soil is loose and friable; and he can plant fully 10 days earlier with a positive certainty that the seed, if good, will germinate; he can cultivate sooner, and with a third less labor to both man and beast; can be stirring the soil in 24 hours after a heavy rainfall. The soil is warmer, and promotes the more rapid growth of the crop, and is less liable to damage from late frosts in spring, or early frosts in autumn, practically lengthening the season for growth

and maturity fully 30 days, or if the weather should be dry, the roots descending deep into the earth bring up moisture from below, producing an abundant yield. Whether the season be wet or dry, the farmer on drained land has a certainty of an abundant yield which enables him to mature his plants without liability of failure. The experience of the past seasons of extreme drought in some localities has fully demonstrated the fact that the drainage protects against damage from this cause.

PRACTICAL SUGGESTIONS.

In the beginning of the work it should be carefully laid out, the inclination marked on grade stakes, and the whole should be platted and carefully preserved for future reference. If it is not possible to complete the work soon, let it be done so as to look forward to the time when it is completed.

In laying the drain, it is well to strictly adhere to the following rules:

1. The drain should have a sufficient outlet for the discharge of the water that may pass through it.
2. The drain should be deep enough to drain the widest space possible from three to four feet and deeper if necessary, to get the water out by a much shorter line, but drain any way, even if you cannot get outlet to drain so deep.
3. The bottom of the drain should be one regular line of descent, so that the current may have a smooth flow from the head to the mouth of the drain.
4. Every tile should be perfect in form and burned, having a clear metallic ring.
5. In laying the tile, take pains to fit the joints closely, as with all care there will be sufficient space for the inlet of the water, and close joints will prevent the letting in of silt of washings.
6. At the junction of the drains, the water should be brought together, flowing as nearly as possible in the same direction, so that the flow of the current may not be obstructed.
7. The size of the tile may be pretty accurately determined by the amount of surface to be drained and the descent of the drain.
8. At the point where the work ceases for the time, secure and note the same, that the work may be readily taken up at any time.
9. If the drains be laid at a distance of 40 ft. apart, 64 rods of tile are required to lay one acre; if at a distance of 50 ft. apart, 52 rods and a fraction will be required, and at a distance of 60 ft. apart, 44 rods.

WHEN LAYING DRAIN TILE REMEMBER

1. To begin the work at the lowest end or outfall.
2. Start deep enough to drain your whole field.
3. To get all the fall possible.

4. To dig your ditch straight. No curves should be allowed in the straight pipe. When they are necessary, use fittings specially made for the purpose.

5. To lay the tile straight. This can be done by using a taut string as a guide and placing the pipe under it.

6. To lay the tile so that every piece has the same fall. In other words, the whole line should have a true alignment and regular grade. This is important.

7. To pack lightly a little dirt alongside of each tile to hold it in place before filling the ditch.

8. To be careful to place the tile tightly against the one preceding. Don't try to leave space between the tile for the water to get in. It will always find a way.

9. To cover the joints with grass, weeds or paper, to prevent the dirt entering before the soil is packed tightly.

10. To fill up ditches carefully and note results.

Kenfield-Leach Co., Printers, Chicago